METEOROLOGICAL\CCAFS\81900\LPLWS

Information last updated: April 2003

Station: Cape Canaveral Air Force Station (CCAFS)

Facility: 81900 [Range Operations Control Center (ROCC)]

External Interfaces:

1. Meteorological Interactive Data Display System (MIDDS)

1. SYSTEM DESCRIPTION

The Launch Pad Lightning Warning System (LPLWS) consists of electric field mill sensors located throughout Kennedy Space Center (KSC) and CCAFS, and associated computer and display equipment. The system is designed to operate unattended, 24 hours per day/7 days per week, with the exception of periodic maintenance. A Base Station Computer (BSC) is used to collect, archive, and relay the data to a Host Computer Function (HCF), which performs the primary processing of the field mill data into lightning data products. A Display Computer Function (DCF) provides graphical and tabular displays of field mill and Center-of-Charge (flash) data, and also serves as an interface for user commands. A block diagram of the LPLWS system is shown in Fig.1-1. Major components are discussed in the following subsections.

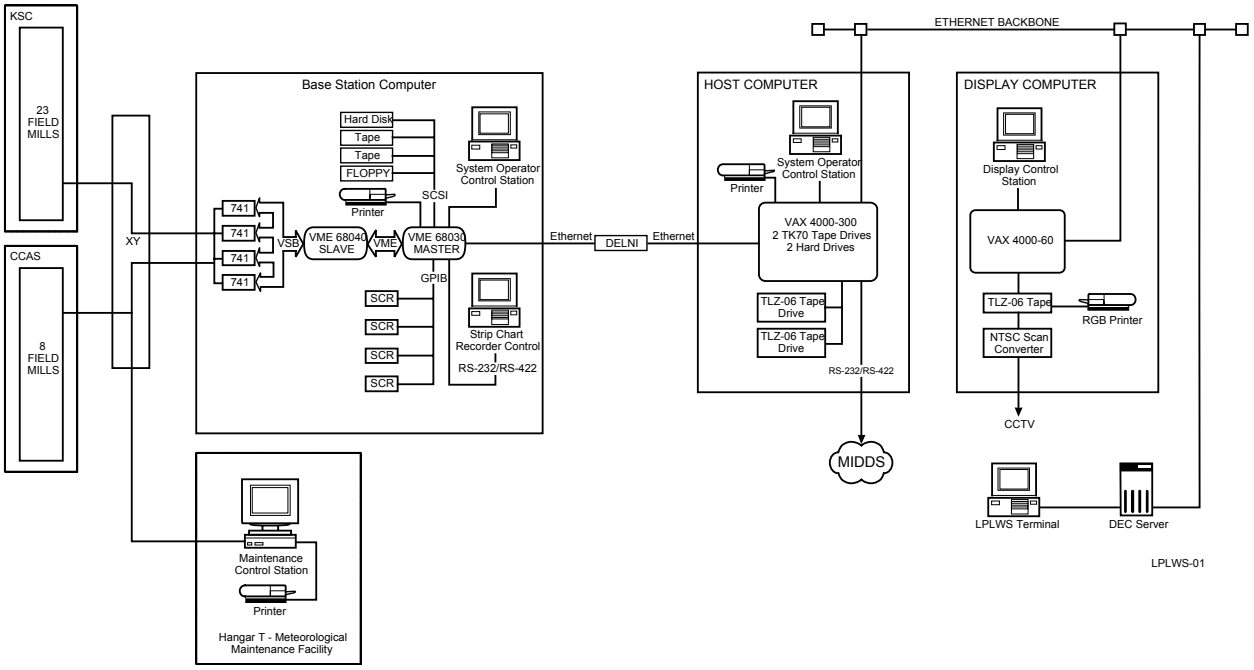

Fig. 1-1. LPLWS Block Diagram

The LPLWS was designed to measure the electric field intensity at ground level. The field mill network consists of 31 electric field mill sites, with one mill located at each site. Measurements of the surface electric field intensity are sampled at a rate of 50 Hz at each field mill site and passed to the BSC once each second. The network includes 23 sites at KSC and 8 sites at CCAFS.

An example of an LPLWS screen display from the DCF at the Range Weather Operations (RWO) center is shown in Fig. 1-2. The display shows the location of each of the field mill sites, the site ID number, and typical 1-minute average electric field values in kilovolts per meter (displayed just below each site ID). Also, shown at the upper right of the display, are the operational mode (i.e., real-time), data time, and Fair/Foul weather indicator. The computed electric field contours, as generated by the National Center for Atmospheric Research (NCAR) algorithm, are overlaid on a local geographical background map.

A tipping-bucket rain gauge is installed at each of the field mill sites. These gauges measure precipitation at each site and provide “ground truth” data for NASA’s Tropical Rainfall Measuring Mission (TRMM) project, a program from NASA’s Mission to Planet Earth. The TRMM satellite was launched on 27 Nov 97 to measure tropical precipitation and its variation from a low-inclination orbit, providing a first opportunity to estimate the vertical profile of latent heat released through condensation of atmospheric water vapor. The “ground truth” data provided from the TRMM rain gauges is used to verify and improve measurement and predictive capabilities of TRMM. As the small collecting bucket fills and tips during rainfall events, each tip is recorded electronically. The tip-counts from the rain gauge are passed along in the field mill data packet once each second.

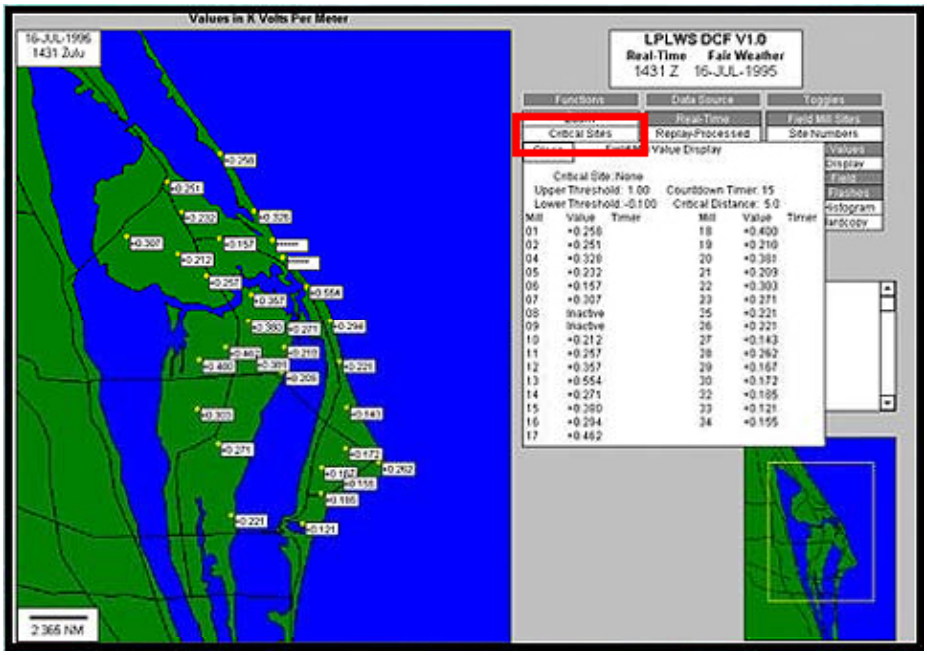

Fig. 1-2. LPLWS Screen Display from the DCF

1.1 Electric Field Mills

The Electric Field Mills are the sensor units of the LPLWS system. A typical field mill site is shown in Fig. 1.1-1., and a close-up of the sensor is shown in Fig. 1.1-2. Each field mill consists of a cylindrical housing suspended 1 meter above ground level. The housing contains a motor that spins a grounded metal rotor blade at a nominal 2,500-rpm. The blade is coaxially mounted with a complementary fixed slotted stator disk, which is insulated and separated from the blade by a small distance (See Fig. 1.1-3). The ambient electric field at the sensor induces a capacitance between the rotor blade and the stator disk, which is detected by onboard electronics and converted into a signal proportional to the electric field strength. This signal is sampled at 50 samples per second (50 Hz) and bundled into data packets, along with timing and status information, and passed via landlines to the BSC in Room 140 of the ROCC.

Each field mill is important to the network, since development of a local cumulus cloud that becomes charged could result in cloud-to-ground lightning that may damage equipment or cause harm to personnel. Table -1 lists the field mills and special notes regarding local site conditions. The geodetic coordinates used for the field mill sites on the LPLWS display must be converted to NAD 1927, Clarke 1866, in order to be correctly displayed with respect to the background map on the DCF. Official coordinates (in World Geodetic Survey 84) are available in the 45 Space Wing Geodetic Coordinates Manual (GCM).

Fig. 1.1-1. Typical Field Mill Site

Fig. 1.1-2. Field Mill Sensor

Fig. 1.1-3. Rotor End of Field Mill Sensor Head

Table –1. LPLWS Field Mill Sites

FIELD MILL SITE	STATION	RAIN GAUGE	FACILITY	COMM. CIRCUIT	SPECIAL NOTES
1	KSC	Yes	F6-2325	2DAM055	Salt and moisture condensation result in high deflections in AM, <100m from ocean, on PlayaLinda Beach, beach erosion threatening the site
2	KSC	Yes	G5-1011	2DAM062	None
4	KSC	Yes	H7-163	2DAM054	Salt and moisture condensation result in high deflections in AM, 100-200m from ocean, on PlayaLinda Beach
5	KSC	Yes	H5-585	2DAM061	None
6	KSC	Yes	H6-1629	2DAM052	PlayaLinda Beach 100-200m from salt marshes, power line along railroad approx. 15m AGL and <50 m from field mill
7	KSC	Yes	H4-1725	2DAM066	None
8	KSC	Yes	H7-1986	2DAM067	None
9	KSC	Yes	J8-754	2DAM053	Salt and moisture result in occasional low absolute value readings, 100-200m from ocean, former bus tour turn-around between Shuttle pads 39A and 39B
10	KSC	Yes	J5-583	2DAM068	None
11	KSC	Yes	J6-1869	2DAM060	None
12	KSC	Yes	J7-2111	2DAM059	None
13	KSC	Yes	J8-2228	2DAM056	Salt and moisture result in occasional low absolute value readings, <100m from ocean
14	KSC	Yes	K8-1403	2DAM057	None
15	KSC	Yes	K7-1557	2DAM064	None

FIELD MILL SITE	STATION	RAIN GAUGE	FACILITY	COMM. CIRCUIT	SPECIAL NOTES
16	KSC	Yes	K8-1648	2DAM069	Unusual percentage of negative readings (reason unknown), <100m from ocean
17	KSC	Yes	L6-75	2DAM070	None
18	KSC	Yes	L5-683	2DAM073	Sunrise Surprise effect, canals within 10m in 3 out of 4 directions
19	KSC	Yes	L7-988	2DAM058	None
20	KSC	Yes	L7-1760	2DAM063	None
21	KSC	Yes	M7-286	2DAM074	None
22	KSC	Yes	M5-1545	2DAM075	None
24	KSC	Yes	95-147	2DAM090	None
25	KSC	Yes	Q6-82	2DAM098	Seasonal corona discharge (during warm weather) from power lines 15m AGL and 10m from field mill, 100-200m from salt water
26	CCAFS	Yes	32326	2DA2901	None
27	CCAFS	Yes	19127	2DA2902	Low absolute value readings (following clearing of vegetation) - reason unknown
28	CCAFS	Yes	00228	2DA2903	None
29	CCAFS	Yes	61629	2DA2904	None
30	CCAFS	Yes	20170	2DA2905	None
31	CCAFS	Yes	74-505	2DA2958	None
32	CCAFS	Yes	50732	2DA2906	None
34	CCAFS	Yes	24434	2DA2908	None

The field mill at each site is located on a concrete pad within a gravel-covered circular area with a nominal radius of 25 feet. The gravel area is located within a larger area of 50-foot nominal radius that must be cleared of all trees, shrubs, and man-made objects. The site is further restricted to have no objects protruding higher than 18 ° above the horizon, as seen from the field mill location. The requirements for the physical layout of

a field mill site are illustrated in Fig. 1.1-4. Specifications for the electric field mill sensors are provided in Table -2.

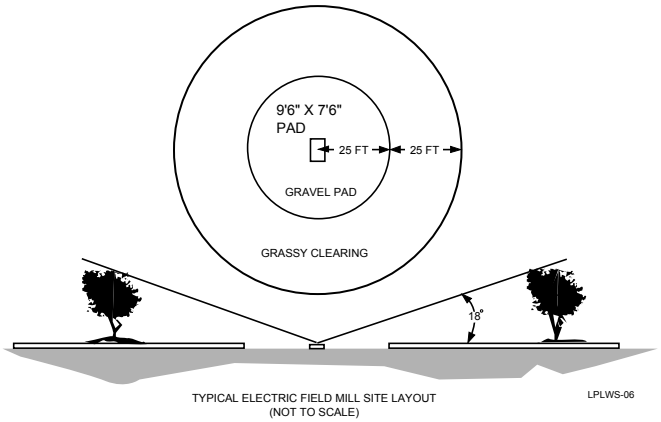

Fig. 1.1-4. Physical Layout of Typical Field Mill Site

Table –2. Electric Field Mill Sensor Specifications

SPECIFICATIONS	
Sensitivity	144 microvolts/volt/meter
Resolution	4 volts/meter
Digitization Resolution	14 bits, signed
Sample Rate	20 millisec, max 40 millisec, split mode
Dynamic Range	+/- 30 kilovolts/meter
Bandwidth	0 to 10 Hz
System Electrical Noise	1 volt/meter (AC & DC)
Work Function Noise	< 4 volts/meter DC < 4 volts/meter AC
Calibration Range (rotor potential)	>= +/- 1/4 full scale, fixed DC voltage, +/- LSB accuracy
Temperature Range (operating ambient)	-5°C to + 50°C
Battery Life (operating)	8 hours nominal
Input Noise	1/2 LSB (0.1 Hz to 1 kHz), max 1 LSB DC, max
External Analog voltage	+/- 10V, max

SPECIFICATIONS	
External rate	40 millisecond
Rain Gauge	Tip Count (single byte)
Time Reference	IRIG-B (from Base Station)

1.2 Base Station Computer

The BSC operates on a continuous basis to accept the incoming data packets from the 31 electric field mill sites and archive the 50 Hz field mill data to tape. The BSC issues an error log, which contains information regarding its own status and the operational status of the individual field mills. It relays requests for changes in operational status received from the Host computer to the individual field mills. The primary software module that performs these functions at the Base Station is WLBASE.

The BSC is a rack-mounted subsystem of the LPLWS, and serves as an intelligent communications buffer and controller for the field mill network. It collects data from the field mill sensors, processes and time synchronizes the data, and sends it via Ethernet to the Host Computer. The BSC consists of two microcomputers in a master/slave relationship and associated peripherals. Peripherals include two ExaByte 8500 tape drives (for data archiving and playback), a System Operator's Console (SOC) with keyboard, monitor and mouse, hard disk and floppy drive, and a dot-matrix printer for output of status and errors. The slave computer (Motorola VME 68040) collects the field mill data via landlines from the 31 active sites and passes the data to the master computer (Motorola VME 68030) via P-Net software over a VME-bus interface. The P-Net software contains proprietary drivers from Bill West Incorporated and was included as Government Furnished Equipment (GFE) from Marshall Space Flight Center (MSFC) as part of the Advanced Ground Based Field Mill (AGBFM) project. The BSC is connected to the two Maintenance Control Stations (MCS), one located in the RWO and a second located in the Meteorological Maintenance Facility at Hangar T, CCAFS.

The MCS is used for remote calibration/ checks of the field mills. The BSC is also connected to the four Astromed MT9500 Strip Chart Recorders (SCR) via a General-Purpose Interface Bus (GPIB) interface for plotting of electric field data for each Field Mill site. Configuration control commands are also sent to the SCRs via the GPIB interface.

1.3 Host Computer Function

The LPLWS HCF is a dedicated, real-time processor that collects, archives and processes field mill data received from the base station. It consists of a dedicated VAX 4000-300 minicomputer executing GFE and in-house applications software under the AOS/VS-II operating system. Also included are two TK-70 tape drive units, two hard disk drives and a Host System Operator Console with keyboard and monitor. It receives 50 Hz field mill data from the BSC via Ethernet Local Area Network (LAN). Although capability exists to process data for 64 mills, only 31 mills are currently active.

The HCF averages every 5 samples from each field mill to produce 10 Hz data for archiving and further processing. The 10 Hz data are analyzed as a function of time to determine if a flash has occurred. Once a lightning flash is detected, the Center of Charge is computed as the point at which the change in the surface electric field is a maximum. This Center-of-Charge is reported to the DCF for further processing and display, recorded on disk and tape, and sent to the MIDDS as a Center-of-Charge (flash) record.

Field mill data for each one-minute period is averaged for every mill, archived and reported to MIDDS using the Field Mill Averages record. A 35-by-35 grid of electric field values is computed using the current one-minute averages and is archived, sent to the DCF for further processing and reported to MIDDS using the Field Mill Grid record. If an update is requested for a site location, a record is sent to MIDDS and logged to the system printer.

1.4 Display Computer Function

The LPLWS DCF consists of a VAX 4000-60 computer that communicates with the Host Computer via Ethernet LAN. A color display monitor, keyboard and mouse are provided for man-machine interface. An RGB-II color printer is connected to produce color hardcopy of screen images.

The DCF is the interface between the user and LPLWS system. It provides color graphical display capability for field mill sites, 1-minute average field mill values, field mill status, Center-of-Charge (flash) location and electric field contours, all against a geographical background map of the KSC/CCAFS area. The DCF receives data analysis products from the HCF and retrieves data for processing and display. It provides ability to display graphically the information generated by the HCF, including data time and date, system status, operational mode (real-time or replay), field mill site locations, ID's and status, one-minute electric field values, electric field contours, flash locations, flash histogram and critical site information. It provides the capability to change site locations, ID's, critical site selection and radius. Flashes and Building Fields generate an alarm condition (audible and visual) on the display if detected. Volume of the audible alarm is user selectable.

An example of a typical LPLWS DCF display is shown in Fig. 1.4-1. The display shows field mill site locations and ID numbers, one-minute average field mill values, electric field contours, critical site selection (in table of Field Mill Value Display) and a Lightning Flash Histogram (cumulative flashes in 5-minute blocks). Letters on the histogram time blocks correlate with the alpha character flash indicators on the map display.

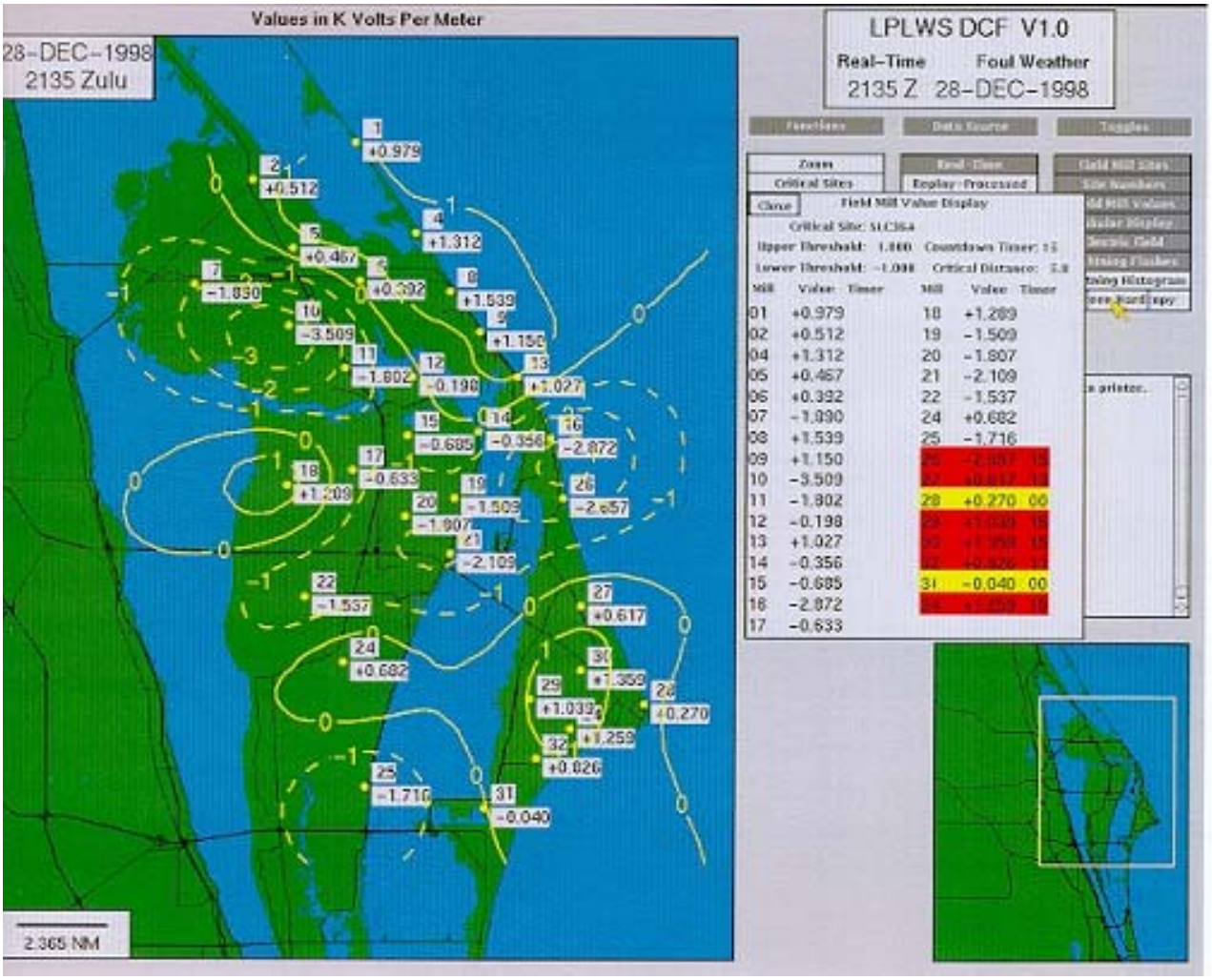

Fig. 1.4-1. Typical LPLWS DCF Display

2. SYSTEM CAPABILITIES

LPLWS provides operators/users with the following primary capabilities:

- Continuous operation (24 hours per day/365 days per year)
- Built-in field mill test capability to ensure valid data and support pre-launch operational tests
- Automatic system status monitoring
- Status information provided to system operator to diagnose system faults from System Operator's Console
- Allows installation of additional instrumented sites and will accommodate up to 64 mills
- Graphical display of current location, operational status, and one minute average surface electric potential for each field mill site
- Generates and displays electric field contours based on 1 minute averages
- Operational mode changes for any field mill (active, inactive, critical site.
- Strip chart recordings of electric field potential vs. time for all operational field mills
- Provides ability to apply a fixed calibration DC voltage on the rotor of a specific mill to simulate ambient electric fields for remote calibration and operational verification
- Measures the ambient electric field with a dynamic range of +/- 30 kV/m to a resolution of 4 V/m at a rate of 50 Hz.
- Generates error logs regarding the status of field mills and the overall LPLWS system

3. CONCEPT OF OPERATIONS

LPLWS gathers, displays and archives measurements of the surface electric field 24 hours a day/365 days per year in support of CCAFS and KSC operations, including launches, propellant transfer and loading, pad operations and general personnel safety.

Operationally, field mills within 5 nautical miles of a launch site are termed "launch critical" sites and are expected to be operational during the pre-launch countdown in order to evaluate the potential for natural or triggered lightning. Such sites may be specially tagged by LPLWS for alarm conditions. Table -3 tabulates the distances between field mill sites and launch sites.

Additionally, field mills provide the same function in the vicinity of areas where propellant loading or handling work on elevated metal structures or similar Range activities require the early forecast of potential lightning.

Table –3. Distances from Field Mill Sites to Launch Complexes (nmi)

FIELD MILL SITE	17A	17B	36A	36B	37B	20	40	41	39A	39B
1	16.5	16.5	15.8	15.9	11.7	13.1	9.9	8.7	6.8	5.3
2	16.9	17.0	16.6	16.6	12.4	14.0	11.0	9.9	8.0	6.6
4	13.7	13.8	13.0	13.0	8.9	10.3	7.1	5.8	3.9	2.4
5	14.8	14.9	14.5	14.6	10.4	11.9	9.0	8.0	6.1	4.8
6	13.2	13.2	12.7	12.8	8.6	10.1	7.1	6.0	4.1	2.7
7	15.8	15.8	15.8	15.8	11.7	13.4	10.8	10.0	8.3	7.2
8	12.0	12.0	11.2	11.3	7.1	8.5	5.3	4.0	2.1	0.7
9	10.7	10.8	9.9	10.0	5.9	7.2	4.0	2.7	0.8	0.8
10	13.2	13.3	13.2	13.2	9.1	10.7	8.0	7.2	5.6	4.5
11	11.4	11.5	11.3	11.3	7.3	8.8	6.1	5.3	4.0	3.3
12	10.3	10.4	9.9	9.9	5.9	7.3	4.4	3.5	2.1	1.9
13	9.4	9.5	8.4	8.5	4.4	5.7	2.5	1.2	0.9	2.3
14	8.3	8.3	7.6	7.7	3.7	5.0	2.1	1.5	1.8	3.0
15	9.0	9.1	8.8	8.8	5.0	6.3	3.9	3.5	2.9	3.3
16	7.7	7.8	6.6	6.7	2.7	3.9	0.8	0.7	2.7	4.1
17	9.2	9.3	9.4	9.4	5.9	7.2	5.3	5.2	4.7	4.8
18	10.3	10.3	10.8	10.7	7.4	8.8	7.2	7.1	6.4	6.3
19	6.9	7.0	6.7	6.7	3.1	4.3	2.6	3.0	3.7	4.7
20	7.3	7.4	7.5	7.5	4.3	5.4	4.1	4.3	4.6	5.3
21	5.8	5.8	5.9	5.9	3.1	3.9	3.4	4.1	5.1	6.1
22	8.4	8.4	9.4	9.2	7.0	8.0	7.5	7.9	8.0	8.3
24	6.1	6.1	7.2	7.1	6.7	6.6	7.3	8.0	8.7	9.5
25	6.0	5.9	8.0	7.7	8.3	8.2	9.7	10.6	11.5	12.4
26	6.1	6.2	5.0	5.1	1.1	2.3	1.0	2.2	4.1	5.6
27	3.4	3.5	2.2	2.3	1.7	0.6	3.7	5.0	6.8	8.3
28	2.4	2.4	0.9	0.9	4.7	3.6	6.8	8.1	9.9	11.4
29	1.4	1.5	2.8	2.5	4.2	3.4	6.0	7.3	8.8	10.1
30	1.7	1.8	1.2	1.1	3.4	2.2	5.3	6.7	8.4	9.8

FIELD MILL SITE	17A	17B	36A	36B	37B	20	40	41	39A	39B
31	2.1	2.0	4.2	4.0	6.8	5.8	8.5	9.8	11.3	12.5
32	1.1	1.0	3.2	3.0	5.7	4.7	7.5	8.8	10.4	11.7
34	0.2	0.3	2.0	1.7	4.9	3.8	6.8	8.1	9.8	11.1

4. OPERATIONAL LIMITATIONS

Although LPLWS computes a Center-of-Charge geographic location based on rapid changes in the measured surface electric field potential, these should not be construed as accurate locations for cloud-to-ground lightning strikes. Based on several years of observation, LPLWS Center-of-Charge locations could be different by many miles with respect to the output of an accurate lightning location system such as LDAR. This is primarily due to the nature of the measurements being made (surface electric field intensity) and the algorithms used to compute the locations of Center-of-Charge. The errors can be especially large for lightning strikes that occur outside the perimeter of the LPLWS Field Mill Network. The LPLWS is primarily an early-warning system of the potential for natural and vehicle-triggered cloud-to ground lightning. In-cloud or cloud-to-ground strikes outside the perimeter of KSC and CCAFS (<50 km from network perimeter) will often result in a measurable field change at ground level that could trigger a Center-of-Charge calculation. Those Center-of-Charge locations, which would lie outside the boundary of the field mill area, will be assigned to locations on the perimeter of the field mill network. This should be kept in mind when making decisions based on LPLWS Center-of-Charge (flash) detections.

Several major discrepancies identified during formal CSCI and system acceptance testing in March/April/May 1994 remain open, but are to be resolved in a future upgrade. Among these are:

- Occasional crash of system during long skips on playbacks or during Raw Replays
- Problems with timing marks and pen deflections on strip chart recorders
- Some raw replay intervals within 30 minutes of “foul weather” were not available
- Occasional halt of one or more strip chart recorders
- Lightning location and detection errors due to GFE algorithms

During formal testing of the TRMM mods to LPLWS in December 1997, an additional problem was discovered in which the block count of the number of flashes could be significantly in error for multiple Raw Replays of a given segment of archived 10 Hz data.

LPLWS software was modified for Y2K and tested formally in May and June 1998. Although a few problems were discovered during the testing, operational workarounds were developed for all problems except one. This problem prevents the replay of

LPLWS data that is more than 27 years old, and will require an upgrade to the VMS operating system to correct.

5. LOGISTICS

Maintenance of the LPLWS sites is divided between several primary and subcontractors. Site power connections to all sites, both at KSC and CCAFS, are the responsibility of the Joint Base Operations and Support Contractor (J-BOSC). J-BOSC is also responsible for grounds maintenance at the KSC field mill sites. On CCAFS, grounds maintenance is the responsibility of a small business contractor managed by the 45th Civil Engineering Squadron. The Shuttle Flight Operations Contractor (SFOC) is responsible for maintaining the communications links to the field mill sites at KSC, while the Range Technical Services (RTS) contractor is responsible for the communications links to the field mill sites at CCAFS. The RTS contractor is also responsible for maintaining the field mill sensors and related equipment at each site (both KSC and CCAFS), as well as the LPLWS BSC, Host computer, Display computer and associated peripherals.